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Energy R and D Policy: Some Analytical Issues

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Objectives:

The purpose of this note is to assist the discussions of the seminar by offering an initial set of analytical distinctions and a partial listing of the issues raised in the recent liturature concerning R and D policy in general and Energy R and D Policy in particular.

Indications of the State of the Art

In 1982 two important meetings took place which might fairly be taken as an indicator of the state of Energy R and D Policy as it relates to developing countries. The first was a meeting hosted by SAREC in January in which 17 people from 15 developing countries met to consider energy R and D policy and the strengthening of energy research capacity in developing countries (Bhagavan and Carlman 1982). The second was the Informal Meeting of Energy Research Donors which met in Ottawa in April and which brought together representatives of 17 aid agencies in an attempt to exchange views of the donor community's policies for funding research relating to the energy sector of developing countries (Adams and Barnett 1982; Porteous 1983).

The details of these discussions are fully reported in the references cited, but for the purpose of this note the key impression given by the meetings was that (with a few notable exceptions) neither the donors nor the developing countries has yet systematically considered their policies towards the allocation of resources to energy research. In both groups there were many countries where even the order of magnitude of the resources involved was not known - however loose a definition of research was applied. There was considerable evidence of wasteful (rather than competitively creative) duplication of effort and the ad hoc short-term nature of much of the research was striking. In the case of the donor group there was a widely held impression that there had been almost no cumulative learning process within the agencies despite the considerable research effort over the previous ten years.

While the problems of recording research activity and formulating policy might be insurmountable in developing countries, particularly for such a 'new' and all embracing field, the lack of policies among donors appears far less justifiable, particularly when they are percieved by developing countries to have a considerable explicit and implicit influence on the direction of energy research within the developing countries.

In both meetings, it was also clear that progress was also limited by the lack of any analytical framework for considering research policy; this was due in large part to the novelty experienced by many of the participants in addressing research policy rather than research itself or the more general issues of energy policy. This lack of a framework can also be seen to have hampered the work of the UN conference on New and Renewable Sources of Energy when they addressed the issue of research (UNERG 1981). Without such a framework there is a tendency for the discussions to get bogged down in arguments about the relative merit of such disparate sources as biogas versus nuclear, or in the generation of impossibly long lists of 'priority' research areas whose only virtue is that it contains all the participants' pet ideas!

However this state of affairs is not unique to energy research. Following an exercise in agriculture similar to the SAREC meeting, Daniels and Nestel (1981) report that it is only recently that policy making authorities have tried to introduce some rationality into the allocation of resources to agricultural research in developing countries despite the existence of research institutions for well over a hundred years. In the developed countries energy R and D policies also leave much to be desired, (see for instance the annual country reviews carried out within the OECD by the International Energy Agency). Indeed it is only recently that the Governments of countries such as Britain and Canada have taken a sector wide view of research in energy rather than planning separately the research related to each fuel or even to each research institute. (Canada 1979; United Kingdom 1979)

R and D in the Context of Technical Change

It is perhaps a universal (and inevitable) criticism of research institutions that they are isolated from the 'real world' of industrial production and the other end-users of their scientific and technological endeavours, almost regardless of how effective they have actually been. But an essential point that emerges from a review of the studies of the effectiveness of R and D is that R and D is usually a part, and often only a small part, of the process that leads to the ultimate goal of technical change and the supply of new technology. Despite this almost self evident truth, the bulk of the literature and policy directives restricts itself almost exclusively to the R and D activities that take place within the perimeter fence of public sector research establishments (this is true for instance in the references cited earlier: Daniels and Nestel: Canada; and the United Kingdom).

In our book (Barnett,Bell and Hoffman 1982), Martin Bell characterised six types of activity that are usually associated with the process of technical change. It is perhaps worth quoting his typology in full to locate the part played by R and D in the process of technical change:

"(i) Activities which create new technical knowledge. The term 'R and D' is usually applied to cover these kinds of activity, but it is important to remember that valuable contributions of new technical knowledge may be made by types of skill and institution which are quite different from those commonly associated with formally organised R and D. Exclusive focus on knowledge-creation by highly qualified and formally trained scientists and engineers working in specialised 'R and D' institutions may neglect the importance and potential of other, more "informal" R and D resources" (on 'informal R and D' see Clay and Biggs 1981)

"(ii) Activities involved in the execution of 'pre-investment' and 'feasibility' studies. These studies will usually draw on existing technical knowledge to produce th broad outline specifications for a particular technical system. They will draw on technical knowledge per se (for example, information about the volume and technical characteristics of indigenous energy resources, soil/climate characteristics, data about alternative conversion devices, and so forth).

They will also draw on socio-economic information (for example, prices of inputs, structures of demand for outputs and prices of outputs) in order to assess the financial and/or economic viability of one or more technical systems. Again one should stress that quite varying kinds of skills and institutions may be involved in carrying out these activities."

"(iii) The production of designs and specifications for technical systems and their component elements. This type of activity will usually start from the initial very broad system outlines generated by 'pre-investment studies' and transform these into much more detailed specifications. These 'engineering' activities will draw on available technical knowledge and transform it into the designs for a particular system"

"The output is not a functioning system itself, but its detailed specifications which are recorded or stored in, for example, drawings, blueprints, schedules, procedures, computer-files or chalk marks on the wall."

"(iv) The Transformation of designs and specifications into the 'concrete' elements of an operating system. This set of activities will usually involve three main elements: It will usually involve production of the 'hardware' components of the systems (for example, turning blueprints into equipment, or transforming drawings and specifications into buildings and infrastructure). It will also usually involve production of the 'software'component of systems (for example, turning general principles about methods for organisation and operation into functioning institutions and specific routines and procedures). Finally, it will also usually involve the 'human' component or production systems (for example, using various forms of training to transform previously inappropriately skilled workers into those with the skills and knowledge that have been specified for the efficient functioning of the system). In such ways, then, this set of activities completes the process of transforming disembodied technical knowledge into the main, integrated elements of an operating technical system - the output is technology that is 'embodied' in fixed capital, in institutions and procedures, and in 'human capital'."

"(v) The storage and communication of technical knowledge and information" (p37)

"(vi) Management"

This last activity is clearly associated with each of the previous five; it is perhaps the most critical in determining the direction and ultimate effectiveness of the technical change process. Deciding what not to do (particularly in resisting the pressures of such groups as aid agencies and particular cliques of local or foreign scientists) may be as important as deciding what to do, when and by whom. Management is also the key component in obtaining the active control of a technology (rather than being a passive recipient). But the costs, time and processes for obtaining such control are often neglected in discussions of R and D policy. We shall have more to say on this later.

Martin Bell illustrates the somewhat limited role of formal R and D play by distinguishing four types of technical change:

(i) System Replication: such as the introduction of a relatively known technology such as biogas

(ii) System Adaptation: such as the installation of a large petrochemicals plant

(iii) Special Purpose Developments: such as the 'tailoring' of known technology to an untypical location

(iv) Genuine Innovation

Only in the last category would formal R and D be centrally involved: in the other cases, the involvement of the R and D instiutions might be slight even though the inputs of technical knowledge might be considerable, they would usually be supplied from other parts of the system.

Such a view of the role of formal R and D in the process of technical change is echoed by elements within the World Bank. Dosik and Weiss stress that although local research capability is vital to the utilisation of new energy technologies other aspects of local technological capacity are of equal importance: namely, the capability to plan, to manufacture and to distribute energy systems. Of the 19 un-named countries they examined, a few had the highest level of institutions, technical skills, expertise in 'social analysis' and policy commitment. One such country had sucessfully produced and diffused a number of energy systems "throughout its rural areas"; another (presumably Brazil) has become a world leader in alcohol fuels. A second group of countries had sufficient policy commitment and had made a start in developing a consistent programme but lacked capability in one or more of the main tasks (technical R and D, social and economic analysis, surveys and planning, manufacture, implementation). In the third group of countries examined, those research capabilities that do exist are limited by their isolation from production and potential users. More generally in terms of the donors' assistance to building the necessary capabilities in developing countries Dosik and Weiss believe that "not much attention has been give so far to the analysis of end-use needs, the development of local capability to undertake research on the technological social and economic impact of renewable energy resources, or to the planning for the widespread utilisation of renewable technologies. The creation of local institutions and mechanisms for marketing and commercialisation for renewable energy technologies has also been neglected. Specific projects have frequently been regarded as ends in themselves rather than a means for securing - through extensive testing, evaluation and adaptation - the widespread use of the technolgies with the country" (World Bank 1981)

The demand for Technical Change

Many of the problems associated with the working of R and D systems can be said to derive from the lack of a strong demand for technical change either from the local productive sectors or from the final users. This fundamental weakness, which represents a major difference in the climates facing research institutions in developed and developing countries, has itself been the subject of much research and literature. At one level it is a problem of the inability of the price mechanism to induce an optimal level and form of research (and thereby necessitating state intervention in the research process of all capitalist societies). And at another level, it is a problem of underdevelopment and the associated problems of what little domestic demand there is 'leaking' overseas. This weakness in the demand for technical change has been extensively reported in the literature, for instance in the stream of studies associated with the programme of research known as the Science and Technology Policy Instruments Project (STPI 1976). Effective technology policy requires effective policies to increase local demand for technical change; this history of the last thirty years shows that this is no easy matter.

Constituents of an Energy Research Policy

The two central issues, the role of R and D in the process of technical change and the weakness of local demand for technical change, lead to a major conclusion: effective R and D policy must be part of a wider set of policies to foster technical change and be part of (and indeed subsequent to) an effective energy policy which in turn must involve, as a minimum, a view of future energy demand and supply and a view of the government policies likely to affect energy demand and supply in the medium and long term future.

It is clearly not possible(or sensible) for each country to adequately research every problem related to its energy sector. The choice of what should be researched could be left to the personal preferences of the individual researchers, and this might be justified with reference to academic freedom. Researchers' preferences are reported to be dominant in many countries' energy R and D activity. And it has to be agreed that much research effort falters because planners (even if they are also eminent scientists) cannot get researchers to do what they do not want to do. Indeed, it has been argued that while research planning may have academic attractions, in practice, the lack of an overall plan has been the great strenth of the US Agricultural Research System (Biggs quoting the study by McCalla 1978)

But three arguments suggest that control through a research strategy of some kind is required:

i) most research funds in developing countries are supplied or controlled by government (usually a much higher percentage than in western industrialised countries which have a large private research sector);

ii) the international scientific community is dominated by people in industrialised countries whose values, reward systems and research priorities do not necessarily coincide with the requirements of non-industrialised societies;

iii) although unproductive research activities are an inevitable part of any research effort, it is possible to discriminate between research programmes in terms of their likely value to society.

Any research strategy must strike a balance between requirments, resources capabilities and the likely activities of others. The variation in these elements between countries suggests that each country will have to develop its own strategy and any world wide generalisation, particularly about

Understanding current and future energy situations also implies a knowledge of the availability of energy reserves. This information is often not known for many developing countries; this is particularly so in relation to the current and potential production of fuels from the biomass, but it is also the case in relation to mineral deposits and hydrosites.

A second element in the formulation of any energy research policy involves a preliminary identification of the possible options available to meet future needs and the research necessary to bring these options into use. Against the background of energy requirements, user needs and resource endowment, a number of options can be identified which offer the possibility of making a significant contribution to a range of likely energy futures. These options will involve both technical and non-technical components and will include a range of policies for the management of energy demand and the means by which technical solutions might be implemented. For each of these options, one of five possible research strategies is possible:

i) <u>to take a national lead</u> in order to provide the country with a firm control over the technical orientation and time scale of the research programme. This might be most appropriate for options that (a) seem essential to the country on most views of the future; (b) are currently neglected by the research efforts of other groups; (c) where existing knowledge is lacking. Examples of this option might be the fuel alcohol programme of Brazil, the small-scale methane technology of India or China, or some aspects of the wood fuel problem in many countries.

ii) <u>to maintain a good technical competence</u> in anticipation of possible future needs. This is appropriate for options which are not of the highest priority but where changes in energy futures or developments by others may make it desirable for the country to enter into the R and D process with a significant level of funding in the future. For some countries, an example of this might be the film processes for producing photovoltaic cells.

iii) to rely on foreign commercial or government interests where these have programmes likely to satisfy the country's requirements. This strategy might be most appropriate for those options where (a) local demand would be insufficient to justify a national research and development programme; (b) where these foreign interests have such well established research capability that national programmes are unlikely to be able to compete; (c) or where the technical superiority of foreign facilities is likely to overtake national programmes. For many countries, this would be the case for large-scale electricity generating plant.

iv) to acquire and maintain the status of an informed buyer. This would be appropriate where (a) there is a need to establish the local resource potentials before committing funds to a more substantial R and D effort, or (b) where the technology is well established outside the country and is likely to be better or cheaper than the local product.

v) to await developments elsewhere. This would be appropriate for technologies which do not currently meet local needs, but might have relevance in the long term, or if substantial breakthrough occurred.

(This scheme is adapted from UK Department of Energy 1979)

In choosing between these research options, developing countries do so in the world context in which:

- energy research resources in developing countries are generally limited (though less so in the newly industrialising countries, the so-called "NICs");

- the bulk of the world's R and D resources is concentrated in developed countries (over 95% is a commonly quoted figure);

- the trade in technology is a process of bargaining, often between very unequal participants.

- the conditions in the rural areas of developing countries differ very greatly from the conditions in developed countries where most of the technology is developed.

Lessons from other Research Fields

Despite Daniels and Nestels somewhat pessimistic view of the state of research planning in agriculture quoted earlier, the field of agriculture does appear to offer a number of insights into the more formal methods that might be adopted to add a greater degree of rationality into the energy research resource allocation process.

It is beyond the scope of this paper to offer a comprehensive review of the liturature (though the time would appear ripe for such a review) but Biggs has looked at the literature relating to agricultural research and has distinguished a number of research approaches which have proved useful (Biggs 1981). First he distinguished between historical (ex post) and planning (ex ante) studies. In the first category he cites examples of five types:

- i studies on the diffusion of innovations
- ii socio-economic research on the impact of innovations
- iii research to estimate the productivity of research
- iv institutional research on the international transfer of technology
- v research on the processes of technology generation and diffusion.

In the planning of research he finds three types:

- i on-farm and farming systems research
- ii resource allocation studies for international, national and commodity research programmes
- iii models for the organisation and management of research and promotions systems.

Biggs review adds weight to the assertion made earlier that it is possible to distinguish between competing research ideas in terms of their value to society. Various indecies and models have been developed for the purpose in agriculture. Biggs suggests that the "Research/Commodity Congruity Index" which shows the extent to which the share of the research budget going to a particular commodity matches the share that commodity represents in the total value of a country's agricultural production, has been most useful as a first indicator of the relevance of research. Other "scoring models" have also proved useful and a variety of checklists have been developed from which energy research policy makers might benefit.

While attempts have been made to construct far more sophisticated quantative models for research resource allocation, their usefullness becomes rapidly limited as their sophistication creates impossible demands for data and their methods are poorly understood by policy makers. The consensus among practitioners appears to be that while making choices about research will always remain a risky business, a number of quite simple 'partial' procedures can provide insights into the likely effects of particular resource allocation patterns and that the knowledge so derived will considerably improve on the almost random allocation procedures currently adopted.

The Location of Research and Comparative Advantage

In spite of the concentration of research resources in developed countries, certain research tasks would appear to be best done in the developing countries themselves. Developing countries have a 'comparative advantage' in that research which is intimately related to each country's unique endowment of physical, geographic, social, economic and political characterisitcs. This is the case with research aimed at the testing, adaptation and diffusion of technology in the context of local conditions and requirements. It is also a characteristic of research essential to the exercise of political and economic control such as the identification of needs, the definition of priorities the formulation of policy and all forms of bargaining. A third category of research for which developing countries have a comparative advantage are those where they are the main beneficiaries of the technology and where research is not carried out by developed countries.

The converse of these arguments would suggest that governments of developed countries (and international research centres dominated by expatriates) would most usefully serve the interests of developing countries by focussing their research efforts on areas which:

a) involve very large amounts of money and other resources;

b) where the results are likely to be applicable to a wide range of conditions within developing countries;

c) where international commercial concerns are uninterseted in applying their research resources because of their inability to obtain monopoly profits to ensure a return on their investment;

d) where basic scientific principles need to be established or where standard research or evaluation procedures need further development;

e) where use can be made of existing sophisticated equipment or highly skilled personnel. Such research is likely to be concentrated at the more basic end of the applied/basic research spectrum; it might involve the compilation, analysis, and dissemination of existing sources of information; and it might incorporate the role of "honest broker" in the process of bargaining over technology.

In agricultural research it was believed that international research had a large role to play (particularly in the development of high yielding varieties of wheat and rice). The same model (the CGIAR system) is now advocated by the World Bank for the energy sector. However, the need for international centres for energy related research has not yet been demonstrated and there are major differences between the needs of agricultural research in the 1960's and energy in the 1980's.

Levels and Types of Research

From what has been said so far, discussions of research policy might be made more effective if participants are specific about what level of policy they wish to refer and what type of research is involved.

On the question of the level of policy there would appear to be three inevitable questions:

- What areas are to be covered by the energy policy? Consider initially sectoral "end uses" such as agriculture, industry, tansport, and domestic rather than energy sources or conversion devices.

- What agencies are to be covered by the policy? Government R and D institutions, universities, private industrial research establishments, foreign researchers and foreign funding.

- What "level" is the policy intended to cover?
  - Central level: Planning Commision, Presidents Office
  - Sectoral level: Ministries, Industries
  - Individual Research Institutions - should universities or other institutions decide priorities within an over-all government budget

On the type of research, past discussions have tended to focus on specific technologies, or particular energy sources or (more rarely) on specific end uses. But it would also appear important to add a second dimension to this 'matrix' and specify what form of research is required for each technology, fuel or end use. One possible typolcgy is suggested below:

A Identification of problems now and in the future
- eg. deforestation

B Understanding the causal connections surrounding a problem
- eg. is deforestation caused by fuelwood use, the need for arable land, over grazing, land tenure, etc.

C Identification of potential options
- technical (hardware) eg. improved stoves, irrigation, food preservation
- non-technical - pricing policy, credit, land reform

D 'Ex Ante' Evaluation of options
- desk
- field - genuine local operating conditions

E Technical Research
- determining state of the art
- filling the gaps - basic research? applied research?
- development of hardware
- adaptation of existing hardware to local conditions

"Software research" related to (at least!)

- finance
- user's needs, purchasing power, perceptions, preferences
- management of energy supply and demand (prices, transport policy, income policy, import policy, etc.)
- effective extension and distribution services
- effective maintenance services
- 'ex post' evaluation/monitoring of impact

Further Research

We have touched on a large number of themes in this note, many of which might benefit from further research, particularly at the level of particular countries and institutions. One unavoidable conclusion is that a necessary first step in the formulation and implementation of an effective policy for technical change are inventories of existing allocations of resources to energy research and related activity. Such inventories might be made more useful if they compared current activity and expenditure with views of likely energy futures facing the country surveyed.

A second step might be more thorough attempts to specify the characteristics of the process of technical change in each country. As a minimum this might describe how the R and D institutions are controlled and their links to their actual and potential clients. Perhaps more difficult would be studies of the relationships between the technology supply system and the factors determining actual (and planned) energy policy.

Quite inexpensive, but fundamental background research might also be carried out on the methodological issues of energy research planning. This might include attempts to generate "scoring models" with which to evaluate research policy options and more systematic attempts to learn from research allocation approaches in other countries and other sectors (notably agriculture) and thereby generate analytical frameworks suitable for setting energy R and D policy in the context of a nation's energy policy.

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